POTTERY AND PLUMBISM.

DR. T. E. THORPE, F.R.S., gave a lecture on Friday evening, May 4, at the Royal Institution, on the results of an experimental inquiry which he has made, at the instance of the Home Office, on the hygienic questions involved in the use of lead compounds in the manufacture of pottery.

After explaining how lead poisoning occurs in connection with pottery manufacture, he described the conditions which a perfect glaze must fulfil, and named the various forms in which lead compounds enter into the composition of the glazing material as ordinarily employed. He pointed out that experience amply demonstrated, both in this country and on the Continent, that "raw" lead is more generally mischievous in its action than "fritted" lead, that is, lead in the form of a complex silicate associated with alumina, lime, &c. This depends on the more ready solubility of the various modifications of raw lead in the animal secretions, and more particularly in the gastric juice. This fact, indeed, is now generally recognised, and in the inquiry which was instituted by the Home Office in 1893, manufacturers whose names deservedly carry authority in the pottery districts strongly urged the substitution of fritted lead for raw lead in all glazes. Unfortunately, however, this recommendation was not enforced. This may have been due, partly at least, to the circumstance that cases of plumbism occurred from time to time in works where fritted lead was exclusively used. The fact is there is fritted lead and fritted lead.

Dr. Thorpe then proceeded to explain the results of a recent inquiry into the conditions which determine the ease with which lead may be dissolved out from a fritt by dilute acids such as are present in gastric juice. In the first place, it was found that, speaking generally, English fritts yielded a far larger amount of lead to solvents than those made in Holland, Belgium, Germany or Sweden. Indeed, some English specimens of fritted lead were found to be hardly less soluble than raw lead, as shown by the following numbers:—

	Lead oxide dissolved, expressed as percentage of total lead oxide present.
Lead silicate, Specimen I.	99·6
,, ,, ,, II.	99·6
Glaze A, made with lead silicate	99·2
,, B, ,, ,, ,,	99·2
Various forms of "raw" lead — Litharge	100·0
Various forms of "raw" lead — Red lead	100·0
Various forms of "raw" lead — White lead	100·0

Next, the inquiry showed that there was no necessary relation between the amount of lead oxide in a fritt and the extent to which it would yield lead to solvents comparable, as regards their action, with animal secretions. Some of the compounds richest in lead were, in fact, among those least attacked by solvents. This is illustrated by the following series of numbers:—

I. *Solubilities practically the same, amounts of lead oxide in the fritt very different.*

	Percentage of lead oxide in fritt.	Solubility per cent. on fritt.
Dutch fritt	18·0	traces
English fritt, A	40·4	0·2
Belgian fritt	22·4	0·7
English fritt, B	41·3	0·7
,, ,, C	52·3	0·4

II. *Solubilities very different, amounts of lead oxide in fritt practically the same.*

English fritt, D	37·9	28·0
,, ,, E	36·2	1·4
,, ,, F	45·8	10·8
Swedish fritt	44·1	2·1

Further inquiry elicited the fact that the extent to which the fritt gave up lead to the solvent depended upon two conditions:—

(1) The existence of a definite numerical relation between the basic and acidic oxides in the fritt, and

(2) Complete chemical union.

The definite numerical relation thus alluded to may be stated in the following terms:—If the sum of the equivalent percentages of basic oxides, expressed as lead oxide, is not more than double the sum of the equivalent percentages of acidic oxides, expressed as silica, the solubility of the fritt, as regards lead, is rarely more than 2 per cent. Any increase in this ratio is attended by an increase in the amount of lead dissolved, and the amount of soluble lead increases very rapidly with even a slight increase in the ratio. The following figures serve to illustrate this fact:—

	Percentage of lead oxide.	Solubility per cent. on fritt.	Ratio.
Dutch fritt, No. 1	18·0	traces	1·34
Belgian fritt, No. 1	21·8	,,	1·44
Dutch fritt, No. 2	19·0	1·2	1·50
Belgian fritt, No. 2	22·4	0·7	1·52
Swedish fritt	44·1	2·1	1·56
English fritt	24·0	0·2	1·57
,, ,,	40·4	0·2	1·68
,, ,,	24·5	0·6	1·70
,, ,,	36·2	1·4	1·79
,, ,,	36·4	2·3	1·87
,, ,,	45·8	10·8	2·61
,, ,,	37·9	28·0	2·92
,, ,,	70·4	67·3	3·26

It was further found that, provided the ratio of acids to bases is below 2, the nature of the basic oxides has little or no effect upon the amount of the lead oxide dissolved. This may be illustrated by the following numbers:—

	Lead oxide.	Alumina.	Lime.	Alkalis.	Solubility per cent. on fritt.
Dutch fritt	19·0	8·1	9·0	4·9	1·2
English fritt	16·2	10·3	8·5	9·2	1·7
Swedish fritt	44·1	5·5	0·9	3·4	2·1

Further evidence of the fact that the insolubility of a complex silicate is determined by the ratio of acids to bases, and is independent of the specific nature of the bases, is afforded by the case of flint glass, which consists essentially of a silicate of alkali united with a silicate of lead. Separately, these silicates are readily attacked by dilute acids. When united, as in flint glass, the compound is only very sparingly soluble. Merely to flux together the ingredients of a fritt, with no regard to its composition as a definite chemical compound, and with no regard to the time or temperature needed to complete the chemical changes, is not the proper way to make a fritt.

In the course of the inquiry it was found that the Continental fritts, which conformed to the above ratio, and were distinguished by their comparative solubility, were very difficult to break up by the action of acids, and yielded only minute portions of soluble matter (much of which, however, consisted of lead) to solvents, whereas the English fritts were, for the most part, very easily decomposed by the same treatment, and gave up the greater part of their lead to solution. This led to the surmise that the Continental fritts consisted, in the main, of comparatively stable chemical compounds, the minute quantity of lead dissolved being due to some lead compound—oxide or silicate—in a state of incomplete chemical union. Experiment showed that this surmise was correct. By treating a fritt, compounded so as to be within the limiting ratio, with dilute acid, by far the greater portion of the soluble or incompletely fixed lead may be removed, and a highly insoluble complex lead silicate is obtained. A fritt, for example, containing upwards of 53 per cent. of oxide of lead, and of which the limiting ratio of acids and bases was about 2, had this ratio lowered to 1·8 and the solubility diminished from 2 per cent. to four-tenths of a per cent., the amount of lead oxide in the product so treated being upwards of 52 per cent.

A number of manufacturers and professional fritt makers, acting in conformity with the suggestions which have been put forward, and in response to the invitation of the Home Secretary to have their glazes tested in the Government Laboratory, are now producing lead fritts having a solubility which is even below the standard provisionally suggested in the Home Office Circular of December last.

Although measures based upon the above facts will no doubt largely minimise the evil of lead poisoning, Dr. Thorpe stated that he was not sufficiently sanguine to suppose that they would altogether stamp out plumbism in the Potteries. It must be clearly understood that complete immunity from lead poisoning can never be obtained so long as lead compounds continue to be used. The true solution is to be found in the more general adoption of leadless glazes. That leadless glazes of a high brilliancy, covering power and durability, and adapted to all kinds of table, domestic and sanitary ware, to china furniture, to tiles, insulators and electric fittings of the most varied kind, are perfectly practicable, was illustrated by reference to the numerous examples of leadless glazed ware which, thanks to the liberality of a number of the manufacturers, were exhibited to the audience. Among them were specimens from Mintons, from the Worcester Royal Porcelain Company, Burgess and Leigh, Barker and Read, Bernard Moore, the Crystal Glaze Company, Hawley Brothers, Defries, and others. Telegraph insulators of Doulton's and Buller's make were exhibited by the Post Office.

Dr. Thorpe stated that leadless glazed ware was now being supplied to a number of the Government Departments and to certain of the London Clubs. He further stated that the London School Board had resolved to insert a clause in all specifications for new works strictly prohibiting the use of any pottery goods involving lead glaze wherever practicable.

The fact that the application of leadless glazes has passed beyond the experimental stage is so obvious that the Secretary of State now proposes to relax the Special Rules, issued by the Factory Department, in regard to the pottery industry in the case of factories or processes in which no compounds of lead are used.

Dr. Thorpe concluded by remarking that every intelligent potter must concede that there is an ample field for investigation by modern methods of attack into problems connected even with the first principles of his art. The craft of the potter largely depends upon the intelligent application of scientific principles. Whether, however, modern science enters into it to the extent that might be desired is perhaps open to question.

There is probably no industry in the world, certainly none in England, so conservative in its operations as that of the potter. The best of English earthenware still enjoys, no doubt, the pre-eminence which the skill and aptitude of Wedgwood and his immediate followers imparted to it. The great potter was fully abreast of the physical science of his day, and was quick to test or take advantage of any discovery which seemed to promise to be of service to his art. But perhaps it may be doubted whether the spirit of Wedgwood actuates his successors to the extent that might be desired. It is at least certain that the exercise of this spirit, that is, the intelligent application of simple chemical principles, would years ago have obviated, to a large extent at least, this evil of plumbism among the pottery workers.

APPLICATIONS OF ELECTRICAL SCIENCE.[1]

I FEEL very much honoured by having been placed in the position I now occupy, and by having to deliver this opening address to the Dublin Branch of the Institution of Electrical Engineers. I believe that we are one of the first branches that has developed into the meeting stage of our existence, and may congratulate ourselves on having passed through our larval transformations safely and rapidly, and on our having been the first to emerge into an imago.

The action of the parent Institution in founding these local branches is worthy of our grateful commendation. We are left perfectly free to develop our own life untrammelled by any rules except such as we would ourselves have necessarily chosen to govern our actions. We have the great advantage of being a branch of a most distinguished Institution of world-wide reputation, and that without paying any extra subscription. I hope that we will add to the life and work of that Institution, and thereby promote both our own interests and the welfare of mankind. Papers and discussions here will be taken as delivered to the Institution of Electrical Engineers, and, if of sufficient merit, will be published in its *Proceedings*, thus securing to us a world-wide publication, while at the same time ensuring that Ireland is credited with the work done.

The history of electricity in the nineteenth century is far too large a subject for an occasion like the present one, but certain aspects of this history convey valuable lessons for the future and may well engage our attention in this last year of the century, and may help us to lay the foundations for further advance in the next. The aspect of the history of electricity during the nineteenth century to which I desire to direct your attention is an object-lesson of how to apply science to further the well-being of mankind. The history of any applied science might be considered in this aspect, but the history of applied electricity is particularly appropriate for being thus considered, for several reasons. The history is condensed within a few years; the discoveries of science have followed one another with extraordinary rapidity, and within a few years after the discoveries were made they have been applied to the use of man. It is just a hundred years since Volta discovered how to make continuous electric currents. Within a few years of that discovery their chemical actions were discovered and electric lights produced, both arc and incandescent. Twenty years afterwards the magnetic effect of an electric current was discovered by Œrsted, its mathematical theory evolved by Ampere, and the law of its intensity worked out by Ohm. Some fifteen years afterwards, Faraday discovered how to produce electric currents by magnetism. Immediately after the discovery of the principle of the conservation of energy it was applied to electro-magnetism, and the foundation of our whole system of electro-magnetic measurement was laid. Faraday's belief in the correlation of electricity and light, following lines suggested by Lord Kelvin, was forged into a consistent theory by Clerk Maxwell, and this theory confirmed experimentally by Hertz. Such, in brief, is the scientific history of electro-magnetism during the expiring century, and on this science practically all the applications of electricity depend.

I may pause for an instant to consider where this theory now lands us. The all-pervading ether has been realised as the means of transmitting light, electricity and magnetism, and we are looking forward to its properties explaining chemical actions and gravitation. We are still looking for a theory of its structure which will give a dynamical explanation of its properties. We know how to express these properties by quantities we call electric and magnetic force, whose laws we know, but whose laws we are, as yet, unable to explain by any structure working on dynamical principles. So far as we know, the properties of electric and magnetic force are explicable upon dynamical principles; so far there is no known necessity for seeking for adynamical properties in the ether; so far we may hope to explain electro-magnetism upon the dynamical principles of Newton's laws without invoking any other principles than those of force and inertia, as expounded in these laws. Until, however, a satisfactory theory of the nature of the ether has been actually invented, there will remain some doubt as to the adequacy of these fundamental dynamical laws to explain all its properties. The direction in which it is most probable that an explanation will be found is in the hypothesis that the ether is of the nature of a perfect liquid full of the most energetic motion. We know that a gas consists of separate molecules in intensely energetic irregular motion. I expect that the ether is a perfect liquid in intensely energetic irregular motion: much more rapid than that of any gas: with a rapidity of internal motion comparable with the speed of light: maybe with enough energy in each cubic centimetre to keep hundreds of horse-power going for a year, if only we could get at it. So far as this hypothesis has been worked at there seems nothing impossible about it, but, on the contrary, much possibility in it, and, to my mind, its inherent simplicity confers on it a great probability.

Be that as it may, we now know that in the electric lighting of our cities, in electric tramways and railways, in electric furnaces and electrolytic vats, and in the other innumerable applications of electricity, we are harnessing the all-pervading ether to the chariot of human progress, and using the thunderbolt of Jove to advance the material welfare of mankind.

Having thus shortly considered the progress of electrical science, the history of the *applications* of electricity may be thus summarised. Shortly after Œrsted discovered the magnetic effect of an electric current this discovery was applied to telegraphy, and Faraday's discovery of how to generate electric currents by magnetism was almost immediately applied to the same use. Telegraphy developed rapidly, and many subsequent discoveries were due to the observations made in the practical application of electricity to telegraphy. This has been developing ever since, accumulating knowledge and applying the accumulations to produce more knowledge and more applications, till all this has resulted in the perfection of the multiplex telegraph and the wonders of the telephone and wireless telegraphy. No other department of applied electricity has had such a continuous development, hardly any interval elapsing between discovery and application in its case, while in almost

[1] Inaugural address to the Dublin Section of the Institution of Electrical Engineers, delivered by Prof. G. F. Fitzgerald, F.R.S. Abridged from the *Journal* of the Institution, April.